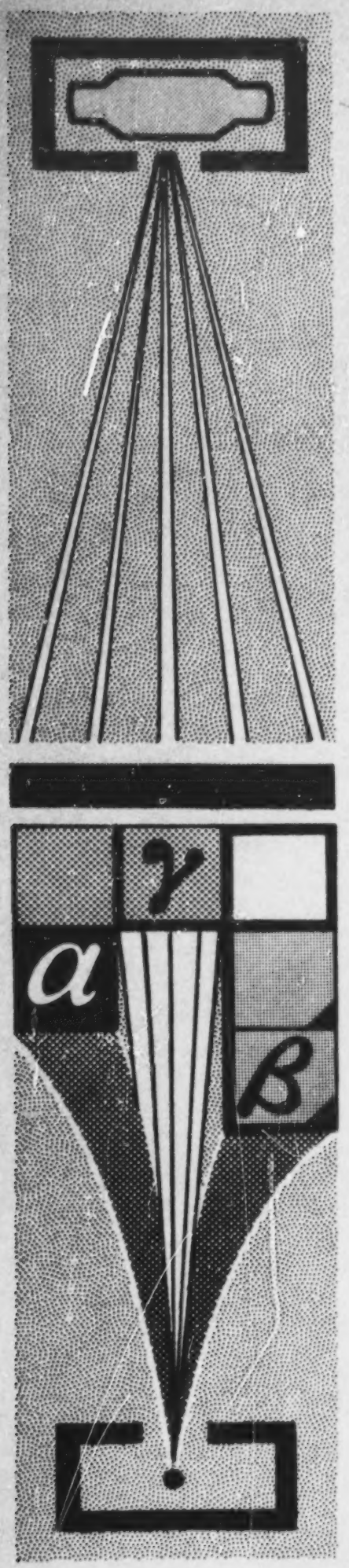

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RADIATION SAFETY RECOMMENDATIONS for X-RAY DIFFRACTION and SPECTROGRAPHIC EQUIPMENT

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

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Environmental Control Administration

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MORP 68-14	Radiation Safety Recommendations for X-ray Diffraction and Spectrographic Equipment

MORP 68-14

RADIATION SAFETY RECOMMENDATIONS for X-RAY DIFFRACTION and SPECTROGRAPHIC EQUIPMENT

by

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Medical and Occupational Radiation Program

Donald J. McDonald
Office of Radiological Health
Pennsylvania Department of Health

OCTOBER 1968

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Environmental Control Administration
National Center for Radiological Health
Rockville, Maryland

FOREWORD

The National Center for Radiological Health conducts a national program for the prevention and control of radiological hazards to public health through (1) surveillance activities, (2) research and development programs, (3) technical assistance to government and other organizations, (4) technical training programs, (5) development of criteria and codes, (6) administration of grants, (7) consultation on international programs, and (8) public information and education activities.

Within the National Center for Radiological Health, the Medical and Occupational Radiation Program deals with reduction of unnecessary radiation exposure of patients, workers, and others incidentally exposed by the use of X-rays, radioactive materials, radiopharmaceuticals, and particle accelerators. The technical reports of the Program allow comprehensive and rapid publishing of the results of inhouse and contractor projects. The reports are distributed to State and local radiological health program personnel, Center technical staff, Center advisory committee members, university radiation safety officers, libraries and information services, industry, hospitals, laboratories, schools, the press, and other interested individuals. These reports are also included in the collections of the Library of Congress and the Clearinghouse for Federal Scientific and Technical Information.

The "Radiation Control for Health and Safety Act of 1968" (Public Law 90-602) effective October 18, 1968, provides that the Secretary of Health, Education, and Welfare shall establish an "electronic product radiation control program which shall include the development and administration of performance standards to control the emission of electronic product radiation." X-ray diffraction and spectrographic equipment, which are discussed in this report, are included within the scope of Public Law 90-602. However, the guides suggested in this report were developed prior to passage of the law and should not be confused with the performance standards authorized under the new law. Nonetheless, these guides may be useful for the subsequent development of regulatory standards, if the Secretary determines that such standards are necessary for the protection of the public health and safety.

I encourage the readers of these reports to inform the Center of any omissions or errors. Your additional comments or requests for further information are also solicited.

James G. Terrill, Jr.
Center Director

PREFACE

X-ray diffraction and spectrographic equipment have become major tools in research and quality control programs. Despite advances in operating techniques and equipment design, radiation injuries have occurred due to operator error and equipment failure. This report resulted from a joint effort of the Pennsylvania Department of Health and the National Center for Radiological Health to develop radiation safety recommendations for X-ray diffraction and spectrographic equipment.

These recommendations are intended for use by operators, administrators, manufacturers, and State radiological health personnel who are concerned with the design and operation of this equipment. The assistance of the many individuals who contributed to the preparation and review of these recommendations is sincerely appreciated.

John C. Villforth
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Radiation Program
National Center for Radiological Health

Thomas M. Gerusky
Director, Office of Radiological Health
Pennsylvania Department of Health

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INTRODUCTION

Until the past few years very little attention has been given to the radiation hazards associated with the use of X-ray diffraction and spectrographic equipment. However, recent studies show that a significant number of reported radiation injuries have resulted from accidents involving such equipment (*1-6*).

Although there are published reports dealing with radiation protection procedures and apparatus designs, there is a lack of generally accepted standards or recommendations for X-ray diffraction and spectrographic equipment. For these reasons, the Medical and Occupational Radiation Program of the National Center for Radiological Health, in cooperation with the Office of Radiological Health of the Pennsylvania Department of Health, has formulated the following recommendations which may serve as a guide to those persons or agencies concerned with this problem. Existing guides have been liberally excerpted (*7-12*).

Those recommendations containing the word "shall" are considered necessary to meet minimal standards of protection. Those using the word "should" are considered advisory, and are to be applied when practical.

DEFINITIONS

Analytical X-ray Equipment: Any device which utilizes X-rays for the purpose of examining the microstructure of materials. This includes all types of X-ray diffraction and spectrographic equipment.

Dose Equivalent: A quantity that expresses on a common scale for all radiations the irradiation incurred by exposed persons. It is defined as the product of the absorbed dose in rads and certain modifying factors. The unit of dose equivalent is the rem. (For radiation protection purposes in these recommendations, the dose equivalent in rems may be considered numerically equivalent to the absorbed dose in rads and the exposure in roentgens.)

Interlock: A device for precluding access to an area in which radiation is present by automatically reducing the exposure rate upon entry by personnel or parts of their body.

Leakage Radiation: All radiation coming from within the X-ray tube housing except the primary radiation beam.

Maximum Permissible Dose Equivalent: The maximum dose equivalent that a person or specified parts thereof shall be allowed to receive in a stated period of time. (See Appendix A.)

Open Beam X-ray Equipment: An X-ray producing device designed in such a way that the primary beam is not completely enclosed by the tube housing-apparatus complex during normal operation.

Primary Radiation Beam: The unscattered or undeflected X-ray beam which has emerged from a port in the X-ray tube housing.

Radiation Controlled Area: A defined area in which the occupational radiation exposure of personnel is under the supervision of an individual in charge of radiation protection. This includes control of access, occupancy, and working conditions for radiation protection purposes.

Scattered Radiation: Radiation that, during passage through matter, has been deviated in direction.

Stray Radiation: The sum of leakage and scattered radiation.

Tube Housing-Apparatus Complex: Those parts of an analytical X-ray device in which X-rays are produced and utilized. This includes the X-ray tube housing, shutter or port assemblies, collimators,

cameras, goniometers, and electronic radiation detectors. This is not intended to include such components as transformers, control panels, or temporary shielding.

X-ray Diffraction Equipment: An analytical X-ray device in which an X-ray beam (usually monochromatic) is made to strike a specimen, causing a portion of the beam to be diffracted. Measurements of certain parameters of the diffracted beam may be used to provide qualitative and/or quantitative information about the specimen.

X-ray Spectrographic (Fluorescence) Equipment: An analytical X-ray device in which a polychromatic X-ray beam is made to strike a specimen, producing X-ray fluorescence which is characteristic of the specimen. A portion of the fluorescent radiation is directed into an analyzing crystal where it is diffracted. The wavelength of interest may then be monitored by a properly positioned detector to provide qualitative and/or quantitative analysis of the specimen.

RECOMMENDATIONS

Administrative Responsibilities

1. For each facility a person shall be appointed to be responsible for radiation safety. This person, designated the radiation protection supervisor or radiation safety officer, shall be responsible for the following:

   Comment: The radiation protection supervisor (who may be the operator) should be familiar with the basic principles of radiation protection and the particular hazards associated with the operation of X-ray diffraction and spectrographic equipment, although he may consult with appropriate experts for detailed advice. The radiation protection supervisor should clearly have authority over matters involving radiation safety, and ideally should be a member of the management staff.

   a. Insuring that operational procedures pertaining to radiation safety are established and carried out so that the radiation exposure of each worker is kept as far below the maximum permissible dose equivalent as is practical.

      Comment: The primary objective in establishing maximum permissible dose equivalent values for occupational exposure is to keep the exposure of the radiation worker well below a level at which adverse effects are likely to be observed during his lifetime. Another objective is to minimize the incidence of genetic effects for the population as a whole. While the risk to individuals exposed to the maximum permissible dose equivalent is considered to be very small, the risk increases gradually with the dose received. For this reason, it is desirable to keep radiation exposures as low as is practical with due consideration to feasibility and efficiency of operation.

   b. Providing instruction in safety practices for all personnel who work with or near X-ray diffraction and spectrographic equipment.

   c. Maintaining a system of personnel monitoring.

   d. Arranging for establishment of radiation control areas, including placement of appropriate radiation warning signs and/or devices.

e. Providing for radiation safety inspection of X-ray diffraction and spectrographic equipment.

f. Reviewing and approving modifications to X-ray apparatus, including X-ray tube housing, cameras, diffractometers, shielding, and safety interlocks.

g. Investigating any case of abnormal radiation exposure to personnel and taking remedial action, if necessary.

h. Complying with all applicable Federal, State, and local rules and regulations.

2. No individual shall be permitted to act as an operator of a particular X-ray diffraction or spectrographic machine until such person has:

a. Received an acceptable amount of training in radiation safety as approved by the radiation protection supervisor.

b. Demonstrated competence to use the machine and radiation survey instruments which will be employed.

c. Received the approval of the radiation protection supervisor.

3. The operator of the X-ray diffraction or spectrographic equipment shall be responsible for all operations associated with that equipment, including radiation safety. In particular he shall:

a. Keep radiation exposure to himself and others as low as is practical.

b. Be familiar with safety procedures as they apply to each machine he operates.

c. Wear personnel monitoring devices, if applicable (see items 10, 11 and 30b).

d. Notify the radiation protection supervisor of known or suspected abnormal radiation exposures to himself or others.

Operating Procedures

4. Personnel shall not expose any part of their body to the primary radiation beam.

5. Only trained personnel, as approved by the radiation protection supervisor, shall be permitted to install, repair, or make other than routine modifications to the X-ray generating apparatus and the tube housing-apparatus complex.

6. Procedures and apparatus utilized in beam alignment should be designed to minimize radiation exposure to the operator.

   Comment: Particular attention should be given to viewing devices to assure that lenses and other transparent components attenuate the radiation beam to minimal levels. When alignment involves working near the open primary radiation beam, the beam current should be reduced in order to lower exposure rates. If a fluorescent alignment tool is used, dimming the room light will permit a significant reduction in beam current. The fluorescent alignment tool should be long enough to permit the operator's hand to be kept a safe distance from the beam. The operator should be familiar with the manufacturer's recommended alignment procedures and copies of these should be available for reference.

7. Written emergency procedures pertaining to radiation safety shall be established for each facility by the radiation protection supervisor and shall be posted in a conspicuous location near each X-ray diffraction or spectrographic unit. These should list telephone numbers of a physician and the radiation protection supervisor and, as a minimum, should include instructions for the following actions to be taken in case of a known or suspected accident involving radiation exposure:

   a. Notifying radiation protection supervisor.

   b. Arranging for medical examination, being sure to notify the examining physician that exposure to low energy X-rays may have occurred

8. If, for any reason, it is temporarily necessary to alter safety devices, such as bypassing interlocks or removing shielding, such action shall be:

   a. Specified in writing, approved by the radiation supervisor, and posted near the X-ray tube housing so that other persons will know the existing status of the machine.

   b. Terminated as soon as possible.

9. Radiation exposure to individuals, either within the radiation controlled area or in its environs, shall be so controlled that the maximum permissible dose equivalent values as set forth by the National Council on Radiation Protection and Measurements (see Appendix A), or Federal, State, and local rules and regulations, are not exceeded.

Personnel Monitoring

10. Operators of X-ray diffraction or spectrographic equipment should be provided with finger or wrist radiation monitoring devices. The supplier of the monitoring device should be notified of the energy of the monitored radiation.

    Comment: The decision as to the need for personnel monitoring devices should be made after first evaluating the likelihood that the operator will be working in close proximity to the primary radiation beam, taking into account procedures such as beam alignment and equipment maintenance. The monitoring device should be so located that the body part nearest the primary beam is monitored. For example, if the operator sets up an experiment working primarily with his right hand, a wrist or finger monitor should be worn on that hand. Monitoring devices worn on the chest or abdomen may provide an indication of the amount of stray radiation to the whole body. It is important to note that the cross-sectional area of the primary radiation beam is usually small and that the monitoring device may not indicate the maximum primary or stray radiation exposure to the operator.

11. Personnel monitoring (preferably finger or wrist devices) shall be required for all workers involved in the use of open beam X-ray equipment.

12. The personnel monitoring data shall be retained as a permanent record by the radiation protection supervisor and shall be available for examination by all personnel concerned.

Area Monitoring

13. Radiation protection surveys should include monitoring for stray radiation in the immediate vicinity of the X-ray apparatus.

    Comment: These surveys, which may be performed by the operator or the radiation protection supervisor, may be necessary for the proper placement of shielding or for the location of barriers which limit the entry of persons into radiation controlled areas.

    Geiger-Mueller portable survey instruments may be valuable for locating stray radiation, although the results are not necessarily quantitative. If accurate exposure measurements are desired, the survey instrument should be calibrated

with a source of low-energy X-rays. Consideration should also be given to possible monitoring errors due to the cross-sectional area of the monitored radiation beam being smaller than the sensitive area of the survey instrument. Defects in shielding may sometimes be best detected by means of films.

Safety Engineering

14. The tube housing leakage radiation, measured at a distance of 5 cm. from the surface of the tube housing with beam ports blocked, shall not exceed 25 mR in 1 hour, and should not exceed 0.5 mR in 1 hour at every specified tube rating.

15. Radiation originating within the high voltage power supply (i.e., transformer and rectifiers) shall not exceed 0.5 mR in 1 hour at every specified rating at a distance of 5 cm. from the housing of the power supply.

16. For X-ray diffraction and spectrographic equipment in which the primary X-ray beam is completely enclosed, the stray radiation at a distance of 25 cm. from the tube housing-apparatus complex, as measured with a monitor appropriate for the energy range monitored, should be reduced to a minimal level and shall be less than 2 mR in 1 hour at every specified tube rating.

17. For open beam X-ray equipment the following precautions apply:

    a. Either easily visible flashing lights or other equally conspicuous signals that operate only when the primary X-ray beam is released (i.e., X-ray tube activated and beam ports open) shall be provided in such a manner as to alert persons to the potential radiation hazard. This signal shall be labeled so that its purpose is easily identified.

    b. The operator should be in immediate attendance at all times when the equipment is in operation. Deviations from this practice should be cleared through the radiation protection supervisor.

    c. When not in operation, the equipment shall be secured in such a way as to be accessible to, or operable by, only authorized personnel.

        Comment: Because the exposure rate at the beam port may be greater than 100,000 roentgens per minute, extreme cautions are necessary to prevent accidental exposure to the primary beam. For this reason, open beam techniques should be used only after all other possibilities have been exhausted.

18. Each tube housing-apparatus complex should be so arranged as to prevent the entry of parts of the body into the primary radiation beam path or cause the primary radiation beam to be shut off upon entry into its path.

19. A shutter status (open or closed) indicator should be provided, on or adjacent to the tube housing, which will automatically indicate the position of each shutter, in a readily discernible manner.

20. A sign or label bearing the words "Caution - Radiation - This Equipment Produces X-Radiation When Energized - To Be Operated Only By Qualified Personnel," or words having similar intent, shall be placed near any switch which energizes an X-ray tube. The sign or label shall use the conventional radiation caution colors (magenta on a yellow background) and shall bear the conventional radiation symbol.

21. A sign or label bearing the words "Caution - High Intensity X-ray Beam," or words having similar intent, shall be placed on or adjacent to each X-ray tube housing. It should be located so as to be clearly visible to any person who may be working in close proximity to the primary radiation beam.

22. A red or magenta warning light with the notation "X-ray On," or equivalent, shall be located on the control panel and shall light only when the X-ray tube is activated. Also, a labeled X-ray tube status (on or off) indicator, preferably a red or magenta light, should be provided on or adjacent to each tube housing so that tube status is readily discernible.

23. Machines which utilize an X-ray diffraction camera should have appropriate ports of the X-ray tube housing arranged so that either:

    a. The X-ray tube can be energized only when the camera collimating system is in place, or

    b. A shutter mechanism allows the primary radiation beam to pass only when the camera collimating system is in place.

24. The coupling between the X-ray tube and the collimator of the diffractometer, camera, or other accessory shall prevent stray X-rays from escaping the coupling.

25. Safety interlocks shall not be used to de-activate the X-ray beam, except in an emergency or during testing of the interlock system. If the interlock system does turn off the X-ray beam, it shall not be possible to resume operation without resetting the beam "ON" switch at the control panel.

26. All safety devices (interlocks, shutters, warning lights, etc.) shall be tested periodically to insure their proper operation. These tests should be conducted once per week and shall be conducted at least once per month. Records of such tests should be maintained.

27. All tube head ports which are not used shall be secured in the closed position in a manner which will prevent casual opening. Port covers shall offer the same degree of protection as is required of the tube housing (see item 14).

28. Permanent shielding should be used in preference to temporary shielding.

    Comment: Lead foil should be used carefully, as it is easily distorted and may permit radiation leaks.

29. X-ray diffraction and spectrographic equipment should be placed in a room separate from other work areas, whenever possible.

Special Requirements for Research Installations

30. Research projects may involve frequent modifications of the analytical X-ray equipment and there is often an associated increase in potential radiation hazards. Special efforts are necessary to control the hazards from such machines:

    a. Radiation protection surveys should be made routinely and shall be made after each modification of apparatus.

    b. Equipment operators shall wear radiation monitoring devices, preferably the finger or wrist type.

REFERENCES

Cited References

(1) HOWLEY, J. R., and C. ROBBINS. Radiation hazards from X-ray diffraction equipment. Radiological Health Data and Reports, Vol. 8, pp. 245-249 (May 1967).

(2) LUBENAU, J., J. DAVIS, D. MCDONALD, and T. GERUSKY. X-ray diffraction and other analytical X-ray hazards: A continuing problem. Presented at the Twelfth Annual Health Physics Society Meeting in Washington, D. C., (June 1967).

(3) MCBRIDE, W. W., and J. LIEBEN. Radiodermatitis from diffraction apparatus. Archives of Environmental Health, Vol. 4, pp. 191-195 (February 1962).

(4) MCLAUGHLIN, J. E., and H. BLATZ. Potential radiation hazards in use of X-ray diffraction equipment. American Industrial Hygiene Association Quarterly, Vol. 16, No. 2 (June 1955).

(5) INTERNATIONAL UNION OF CRYSTALLOGRAPHY. Radiation hazards associated with X-ray diffraction techniques. Acta Cryst., Vol. 16, pp. 324-328 (1963).

(6) ATOMIC ENERGY COMMISSION, DIVISION OF OPERATIONAL SAFETY. A Summary of Industrial Accidents in USAEC Facilities, 1965-1966. TID-5360 (Suppl. 6).

(7) BEU, K. E. Safety considerations in the design of X-ray tube and collimator couplings on X-ray diffraction equipment. American Crystallographic Association Apparatus and Standards Committee for 1962.

(8) MINISTRY OF LABOUR. Code of Practice for the Protection of Persons Exposed to Ionizing Radiations in Research and Teaching. London: Her Majesty's Stationery Office (1964).

(9) COOK, J. E., and W. J. OSTERKAMP. Protection against radiation injury. International Tables for X-Ray Crystallography, Vol. 3, Section 6, Birmingham, England: Kynoch Press (1962).

(10) INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION. Recommendations of the International Commission on Radiological Protection. Report of Committee III on Protection Against X-rays up to Energies of 3 MeV and Beta-and Gamma-Rays from Sealed Sources, New York, N. Y.: Pergamon Press (1960).

(11) NATIONAL BUREAU OF STANDARDS. Safety Standard for Non-medical X-ray and Sealed Gamma-Ray Sources. Part I, General, Handbook 93 (April 1966).

(12) NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Medical X-ray and Gamma-ray Protection for Energies up to 10 MeV, Equipment Design and use. Recommendations of the National Council on Radiation Protection and Measurements, NCRP Report No. 33 (February 1968).

Additional References

BOGGS, R. F., and T. M. MOORE. A summary report on X-ray diffraction equipment. U.S. Public Health Service, National Center for Radiological Health, 12720 Twinbrook Parkway, Rockville, Md. 20852.

HAMBLING, P. G., and C. F. SAMPSON. Safety Attachments for X-ray Diffraction Apparatus. AWRE Report No. 0-102/66, United Kingdom Atomic Energy Authority.

KAELBLE, E. F. (Ed.). Handbook of X-rays for Diffraction, Emission, Absorption, and Microscopy, New York, N. Y.: McGraw Hill Book Co. (1967).

NATIONAL CENTER FOR RADIOLOGICAL HEALTH and ELECTRONIC INDUSTRIES ASSOCIATION. Conference on Detection and Measurement of X-radiation from Color Television Receivers. Available in two parts: Technical papers and discussions (edited by Dr. Robert Elder and Dr. John Sheldon). Conference held in Washington, D. C., March 28-29, 1968.

NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS. Radiation Protection in Educational Institutions. Recommendations of the National Council on Radiation Protection and Measurements, NCRP Report No. 32 (July 1966).

PENNSYLVANIA DEPARTMENT OF HEALTH. Regulation for Radiation Protection, Article 433, Harrisburg, Pennsylvania (1961).

RUDMAN, R. X-ray diffraction analysis, Part One-Safety and Generators. Journal of Chemical Education, Vol. 44 (January 1967).

APPENDIX A*

Maximum Permissible Dose Equivalent Values

	Average weekly dose[a] (rem[c])	Maximum 13-week dose (rem[c])	Maximum yearly dose (rem[c])	Maximum accumulated dose[b] (rem[c])
Radiation controlled areas—				
Whole body, gonads, blood-forming organs, and lens of eye----	0.1	3	—	5(N-18)[d]
Skin of whole body----------	—	10	30	—
Hands and forearms, head, neck, feet, and ankles----------	—	25	75	—
Environs—				
Any part of body----------	.01	—	0.5	—

Notes:

[a]For design purposes only.
[b]When the previous occupational exposure history of an individual is not definitely known, it shall be assumed that he has already received the full dose permitted by the formula 5(N-18).
[c]The dose equivalent in rems may be assumed to be equal to the exposure in roentgens.
[d]N = Age in years. (Must be greater than 18.)

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*from Permissible Dose from External Sources of Ionizing Radiation (1954), National Bureau of Standards Handbook 59 including 1958 Addendum and Statement by NCRP in Radiology, Vol. 75, July 1960.

APPENDIX B

Characteristic Spectra for Common Analytical X-ray Tube Targets

Target	Characteristic Wavelength			
	K_a		K_b	
	Angstrom	KeV	Angstrom	KeV
Copper	1.54	8.01	1.39	8.92
Molybdenum	0.709	17.5	0.632	19.6
Iron	1.94	6.41	1.76	7.07
Tungsten	1.48*	8.40	1.28**	9.67
Chromium	2.29	5.42	2.08	5.94
Nickel	1.66	7.48	1.50	8.24
Cobalt	1.79	6.94	1.62	7.65
Silver	0.559	22.2	0.497	25.2

*L_a

**L_b

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This report details radiation protection recommendations for X-ray diffraction and spectrographic equipment, including guidelines for administrative responsibilities, operating procedures, personnel monitoring, area monitoring, and safety engineering. The report is directed to operators, administrators, governmental health agencies, and manufacturers.

KEY WORDS:

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